THE PASSING OF SCIENTIFIC MATERIALISM.

ATOMISM AND THE ETHER.

FROM the earliest historic times, thoughtful minds have addressed themselves to the problem of the composition and the ultimate nature of the external world. When the phenomena of experience have been thought as inhering in substance and the attributes by which substance is known are projected outward as objective, not only to *myself*, but also to absolute subjectivity, that is, when the objective phenomena are regarded as having an independent external existence, the next step is their unification into an objective world. This dualism between an absolute subject and a universal object is one that pervades all thinking, simply because it is the first product of thinking.

Practically, we know the external world as a succession of phenomena appearing as different modes in extension. These three categories of our knowledge, time, space, and mode, are necessary forms of our thought. The process of cognition is a process of integration, the final extreme of which is the production of an external unity to correspond with the internal unity of self.

As certain phenomena are affirmed as attributes of a substance, all attributes are integrated as a totality of substance in a unity, which is our world of experience. This we philosophically construe as the universe. Just as the few and disconnected points of irritation in the retina are blended into a field of view without breaks or lacunæ, when reflected on the consciousness, so the paltry, scattered reactions upon the *sensorium commune* that make up our individual experience are reported in our thinking as a continuous

extended world. There are no breaks in it. Nature, our nature, abhors a vacuum.

This thought of an external continuum may be derived from a peculiar and very "fortunate" limitation of our knowledge. There is, e. g., no mechanism for perceiving an hiatus in inner experience. Temporal relations are all dynamic. Rip Van Winkle might extend his sleep twice ten thousand times its reported length, but, on awakening, he could know nothing from inner testimony. Inner experience is, and must be, a continuum. Outer experience is reported in the same terms.

Again, space is constructed out of temporal (successive) elements by psychical geometry. The angular deviation of eyes, recorded as muscular sensations of accomodation and similar movements correlated with successive experiences related to these sensations, are connected with the formation of space conceptions, whatever the intuitional school may postulate as something prior to this creation. Space becomes a continuum; therefore, it is a geometric and not an arithmetical construction.

In the case of mode, the idea of a continuum is later in arising. for black is contrasted to white as distinct from, or even opposite to, the latter; and it is only later that we arrive at the apparently paradoxical result that all white is more or less black, and black is somewhat white, and that intervening colors express in their own way a sliding scale of intervening values.

This last analogy is misleading, for it is in the series of excitations and not in the sensations that we find a continuum. The two fundamental forms of mode are identity and unlikeness or dissimilarity. Mode is our reaction to the filling of our forms of space and time,—the latter directly, the former as reflected in objectivisation.

In the long run, therefore, all of these necessary categories of our thinking help us to form an external unity or world, after which metaphysics postulates it as a universe or sets upon it the seal of the absolute.

Science sets forth with the utmost confidence to make conquest of this external world, but only, so far, to return to the stronghold

of individualistic experience, humiliated and baffled. We do not know, and can make no adequate expression for, the reality which constitutes this world of ours. Three characteristics are, indeed, given by the necessities of constructive thinking: the world is unitary, it is continuous, it is dynamic.

All attempts to evaluate the world of experience may be said to fall in one or other of three classes, as follows:

1. *Atomism.* Some minds are arithmetical. All quanitative relations are thought as numerical. All wholes are conceived as made up of units. A world must for them be the sum of all the units of experience, and these must correspond to external units. Such units, since we detect in them relations of "more and less," must be divisible into smaller units; but there will be no point at which they will disappear, but there must be a lower limit of divisibility. By such reasoning, we arrive at indivisible units or atoms, in which inhere all the properties or attributes of the world as a whole, or of various things in particular.

2. *Plenism.* Other minds are geometric and conceive of quantity as continuous. Units are artificial measures of quantities, which increase or decrease by infinitessimal amounts, that is, by continuous activity. The qualities or attributes of the world or of things in particular are only explicable as inhering in a universal substance, co-extensive with the universe and capable of manifold forms of expression.

This interpretation finds many fatal defects in atomism and points out that atoms acting across empty spaces violate the necessities they were invented to satisfy. If acting requires to inhere in a substance, what becomes of activity when passing through a vacuum from one atom to another? In vain, atomism borrows ether from the plenists to fill the chinks between the atoms. The geometrical school states that a plenum or universal substance fills all space and that activity resides in it and is propagated through it. It is even possible to invent mathematical expressions for the individualised manifestations of the activity in the plenum, such as may be studied in the discussion of the vortex atom.

3. *Energism or Spontaneity.* The two schools already named

have shared the honors and divided the field of physics between them. No other possibility has been recognised till lately by modern physicists. These two schools have in common a philosophical postulate, which is not supposed to require proof—and this is very fortunate indeed, for it could never secure it. This postulate is that all activities or attributes must reside in something which is not active. This matter is the physical substitute for the philosophical or psychological construct, "substance." It is by nature unknowable, for it could only be known by its properties or activities. But we do not know them as properties of *it*, but create *it* to explain the continuance or reappearance or relations of the activities.[1]

Activities are discovered to occur in my mind in certain relations, and these relations are the basis for a postulate called "matter." So fixed is the idea that attributes inhere in something, of which they are attributes that language almost refuses to describe any other possibility. But the energist or advocate of spontaneity demurs to this conception as irrelevant. Why should we postulate the unknown to explain the known? True, "standing in relation" is the most important thing about activities. Activities cohere in relations of sequence and similarity, but why invent a matter, entirely unlike the activity and unthinkable apart from the activity, as its ground?

The efforts of physicists have so far failed to afford a consistent and rational explanation of, or expression for, either atom or plenum. The nearest approach to such expression, mathematically, is inconsistent with either and would apply better to activity freed from the limitation of plurality and discreetness imposed by atomism, on one hand, and the impossible combination of imponderability and elasticity, on the other. When the plenists ask us to conceive of gravitation as the effect of an ether itself imponderable, we are fain to seek the camp of the atomists, who speak of ponderable points acting on ponderable points through imponderable space—or to abandon both.

[1] Lord Kelvin defines matter as the rotating parts of an inert perfect fluid, which fills all space, but which is, when not rotating, absolutely unperceived by our senses.

The energists claim that there is no need for either conception, but that substantiality is expressed by relation among activities. Activities are positive realities whenever they are shown to belong together. The belonging-together is the substantiality sought, and to seek further is illogical. A relation is a real thing and expresses a law of organisation. The organisation is the organism. We talk about cold *iron* and hot *iron,* because, of the group of properties we connote under the word "iron," certain ones are observed to vary, and others are, relative to our means of observation, constant. Strictly, however, we should say hot-iron, cold-iron, and cold-hard-black-smooth-iron and hot-softer-grey-rough-iron, etc., as our knowledge of the variables grows. What, after all, makes "iron" a species by itself as against other aggregates of properties called copper, etc., is an organic coherence or belonging-together.

To the spontaneity school have usually belonged philosophical minds who have refused or been unable to attempt an application in detail of their system to the practical needs of human science. Even the practical men who recognised the philosophical correctness of this standpoint, were constrained *in praxis* to use the language of practical physics and chemistry. Hegel's ideas and Schopenhauer's *World as Will and Idea* have never found a place among the symbols of the chemist or the formulæ of the physicist.

After the few introductory words, we may take up the teachings of the three schools more in detail.

THE ATOMIC HYPOTHESIS.

The most complete account of the opinions of the ancient atomists is to be found in the works of the Roman poet Lucretius. Democritus was the founder of the atomic theory as we know it, though it is probable that the two ideas of nature as a plenum and of an infinity of indivisible parts had existed in the philosophical systems of Egypt and India at a much earlier date. Whether we regard the atomic theory as a result of an arithmetical way of treating quantity, or as a product of experience in which the divisibility of units into still smaller units is experimentally realised, it has nevertheless appealed to a certain class of minds with irresistible

power in all ages. The atomists made the distinction between matter and space, and regarded the atoms as indivisible particles of matter scattered in space. The physical analogy is a mass of sand, in which the particles may be all alike, at least in some respects. The necessity for voids was a supposed result of the necessity for motion.

> "Quapropter locus est intactus, inane, vacansque
> Quod si non esset, nulla ratione moveri
> Res possent; namque, officinum quod corporis extat,
> Officere atque obstare, id in omni tempore adesset
> Omnibus: haud igitur quicquam procedere posset,
> Precipium credendi nulla daret res."
>
> *De Rerum Natura,* 335.

The atoms of Heraclitus are indivisible units differing in size, form, and weight. All changes in nature reduce to changes in place or aggregation of atoms. The atoms group themselves in various complexes more or less analogous with the modern molecule, the differences in which result from the diversities in the arrangement of the inherent atoms. Aside from atoms, there is only empty space, but this space has an objective existence, although called the non-existent as contrasted to the atoms as the existent. Democritus himself says that the existent is no more real than the non-existent, a statement which reminds us of the famous Hegelian aphorism that being and non-being are the same. Perhaps, it is to be explained that the agent and the sphere for the activities of the agent are two equal necessities of thought, or that one cannot think of phenomena apart from the limitations that define and make possible the recognition of these phenomena.

The atoms were supposed to be in continuous motion among themselves and to group themselves temporarily in accordance with uniformities or harmonies in such motions. But, as the activities of atoms are, after all, unexplained, a principle is postulated which has generally been termed necessity, ἀνάγχη. This is more like what we have called "ground" and may represent an implied organism—a view that may, perhaps, seem supported by the atheistic tendencies of the atomists.

Anaxagoras supplied the corrective by substituting for necessity the νοῦς or *Nous,* the conscious activity, a teleological principle. This gives to the atom the attribute of spontaneity and forms a link with the energic school. For Anaxagoras the atoms were innumerable, simple, inert bodies in chaotic distribution, until set in activity by the *Nous,* which, accordingly, arranges them into an orderly universe or organism.

In many respects, the monadology of Leibnitz resembles atomism. In making the idea of substance the foundation of his philosophy, Leibnitz resembled Spinoza, but Leibnitz was arithmetical, while his predecessor was geometrical. The substance of Leibnitz, while a living activity, activity being the very nature of substance, finds individual expression in a multiplicity of active monads, each different from the other and each an indivisible point. In this respect they are like Boskovitch's atoms, but, in reply to the objection that no number of unexpected points would make an extended universe, Leibnitz replies that space has no objective reality, it is only a vague subjective concept.

The monad is not only active, it is also living. Each monad is a microcosm and mirrors the universe. It is fundamental to Leibnitz's system that the activities of every monad imply those of all others. These activities, as related to individual monads, are repulsions, but they unitedly form an equilibriated whole. All things are compounds if monads. Matter in the usual sense does not exist. Each monad has a certain mentality in attribute and a certain vague or clear consciousness. The equilibrium of all these conscious activities is the perfect divine reason. While monads do not affect each other directly, they move in a state of equilibrium in which one is reflected in all and all in one,—the pre-established harmony.

Boskovitch, like Leibnitz, regarded atoms as mere centres of force, the result of whose coexistence is that no two atomic centres can approach each other within a certain distance. This approaches to energism, but Boskovitch's atoms have position in space, are capable of motion, in a continuous path, and possess a certain mass, so that a certain amount of force is required to produce a change of motion. The atom is endowed with a potential force, and two atoms

will repel or attract each other, with a force depending on their distance apart, and, for distances greater than about one-thousandth of an inch, this attraction varies inversely as the square of the distance, while the law of repulsive force is not known. The ultimate force is repulsion which increases without limit, as the distance increases without limit, so that no two atoms can ever coincide. All action between bodies is action at a distance. No such thing as contact between bodies occurs in nature.

Swedenborg seems not only to have adopted an atomic hypothesis, but to have anticipated modern stereo-chemistry, by suggesting various geometrical groupings of atoms as causes of the peculiarities of the resulting molecules.

When Boyle and Lavoisier had developed the idea of elements and elementary discreteness, the idea of the atomists, which had been revived by Gassendi, was seized upon by Newton to serve in his physical speculations. The establishment of the fact that for any given portion of matter extension is variable but mass is constant, made the adoption of some form of atomism inevitable.

Bryan and William Higgins developed the atomic hypothesis along theoretical lines. The former, in 1775, recognised seven elements composed of "atoms homogeneal, impenetrable, immutable, in figure inconvertible, and globular." William, a little later, promulgated the idea of the union of atoms to form molecules, though he was unable to formulate the quantitative law for their union.

To Dalton, more than to any single writer, perhaps, we owe the formulation, in acceptable form and with convincing data, of the atomic hypothesis in its modern dress. Dalton was undoubtedly greatly influenced by Newton's corpuscular emanation theory, and his opportunity was due to the work of many others, through whose labors the constancy of matter had been postulated, elements had been differentiated, and the beginnings of pneumatic chemistry made. When studying the diffusion of gases he was impressed with the idea that atoms of different substances must be different in size. Upon applying this hypothesis in chemical problems, he discovered that for each element there is a definite combining value, i. e., that a relative weight of its atom could be assigned. It was

known prior to this time that substances unite in definite proportions. The law of definite proportions found its explanation in the impossibility of dividing atoms, so that the resulting weights of a compound must contain the weights of the uniting atoms as factors.

The atomic theory, as formulated anew by Dalton, which portrayed chemical union as a juxtaposition of atoms, co-ordinated the known relations and gave to chemistry a quantitative basis or law. The tables of Richter and Fischer supplied materials, and the new formulæ of Berzelius assisted to make the new system practicable. Dalton's tables of equivalents were rough approximations, and his own success as an experimenter was limited, but he opened the way and devised the method which, in the hands of Berzelius, who supplied what Dalton lacked, became fruitful, and the new notation grew more complete and was soon generally accepted.

Physicists were, naturally, quite as much interested in the constructions growing out of the atomic hypothesis as chemists, though both were for a while profoundly influenced by the metaphysics of their time. When Gay-Lussac, in 1808, the same year as the publication of Dalton's *System,* showed that combination between gases always took place in simple relations by volume, and that all gaseous densities were proportional either to the combining weights of the several substances or to rational multiples of them, the new era, the era of gaseous physics, had opened. Avagadro generalised the facts and formulated the law that bears his name: "Equal volumes of gases, under like conditions of temperature and pressure, contain an equal number of molecules." The distinction between atoms and molecules (the smallest aggregate of atoms in combination) requires to be constantly in mind, or the mistakes of the earlier chemists and some later physicists may be repeated.

To the above must be added the following: *Boyles Law*: "In a given mass of any gas kept at a constant temperature, the pressure per unit of area upon the containing surface increases in the same proportion as the volume occupied by the gas is diminished." *Charles's Law*: "If the density be constant, the pressure is directly proportional to the temperature measured from the absolute zero, —273 centigrade." *Dalton's Law*: "In a mixture of gases, when

there is an equilibrium, each gas behaves as a vacuum to all the rest."

It was at one time believed that these phenomena could be explained by recourse to mutually repulsive forces acting between the parts of which the gas is composed (molecules and the like); but experimental proof has been offered that not repulsion but attraction exists between molecules. Regnault, for example, by observing deviations from Boyle's law when the density of gases is greatly increased, showed that the pressure is less than that law requires, indicating that the interfering force is attractive. Joule and Thompson conducted experiments on the thermal variations during expansion of gases which also showed that the forces between molecules, though small, were actively attractive.

Such considerations led to the kinetic theory of gases, which explains the intrinsic energy of a gas as not residing in the potential energy of intramolecular forces, but mainly in the kinetic energy of the molecules themselves, which are assumed to be in a state of continual relative velocity. The physical theory of heat compels us to regard the intrinsic energy of any gaseous mass as dependent largely upon temperature, so that it follows that, if this intrinsic energy is found in the form of kinetic energy of the moving molecules, the average kinetic energy of the molecules throughout the mass must be a function of the temperature. When several kinds of molecules are in motion and acting on one another, the mean kinetic energy of a molecule is the same whatever its mass, the molecules of greater mass having smaller mean velocities.

If equal volumes of two gases are at equal pressure, the kinetic energy is the same in each. If they are also at equal temperature the mean kinetic energy of each molecule is the same in each. If, therefore, equal volumes of two gases are at equal temperature and pressures, the number of molecules in each is the same, and, therefore, the masses of the two kinds of molecules are in the same ratio as the density of the gases to which they belong.

It is not necessary to go into the processes by which the size and velocity, as well as the mean path, of the molecule have been calculated. The mean path of a molecule of hydrogen is given at one 10,000th of a millimetre. About two millions of molecules of

hydrogen would form a row a millimetre long. Since the molecules of organised matter are very complex and so much larger than molecules of hydrogen, it has been computed that about two million molecules of organic matter might constitute a fragment visible under a microscope. If these conceptions were true, they would have an important bearing on those theories of heredity that require for their application the existence of pangens, micellæ, ids, or the like. The size of the resulting germs would, upon the above calculations, soon become quite unmanageable and impossible. Of course, we shall see later that, even on the atomic hypothesis, we may be dealing with ultimate particles (electrons) a thousandth the size of the atom, so that the "ids" *et id genus omne* again find a realm for their imagined operations.[2]

When we assume that atoms of every pure (unmixed) substance are all alike among themselves, then Dalton's law of multiple proportions follows of necessity, and all relations of mass in chemical compounds must be regulated by the masses of several atoms. There exists, then, for each element a definite number, which expresses the quantity of that element that may enter into compounds. These numbers for the various elements are relative, or are really ratios. These numbers are the combining weights, or more properly, the combining masses of the elements, and are commonly but incorrectly called the atomic weights.

While, nominally, these atomic weights express the ratio of the combining weight to that of hydrogen, assumed as unity, for practical reasons the assumption is made that oxygen has a weight of 16 as compared to hydrogen, and the comparisons are made direct with oxygen and reduced to a theoretical unity on that basis. As a matter of fact, if O is 16, H is about 1.003 or 1.005.

A very important corollary of the atomic hypothesis was that suggested by Prout in 1815 and elaborated by Meinecke in 1817. Prout believed that there is a fundamental substance or protyle out of which the various atoms are formed by union in various proportions, etc. Hydrogen he at first supposed to be, or to contain, the

[2]An interesting discussion of methods for determining the size of molecules is given in Risteen's *Molecules and Molecular Theories.*

protyle, and, as a consequence, it was assumed that the atomic weights of all elements must be multiples of that of hydrogen or some aliquot part of it, i. e., of the protyle composing it. Thomas Thompson disseminated this idea in England, but, in fact, it is a suggestion which will occur of itself to every thoughtful student of chemical quantities.

Dumas and Stas found errors in the work of Berzelius and showed that the ratio of carbon and hydrogen is as 12 : 1 and that of nitrogen to hydrogen as 14 : 1. This seemed a long step toward experimental proof of the protyle theory. The result of the most careful quantitative work so far does not support the supposition, and Dumas was obliged to divide the weight of hydrogen by 4 in order to secure the desired factor, and this is so small a number as to be quite within the range of experimental error in determining the atomic weights by present methods. It will be seen later that recent results seem to indicate that the factor may be hydrogen divided by 1000, not by 4, so that this difficulty is not so serious as was supposed, provided we accept the electron as the modern representative of the protyle.

However, there is a real approximation to such a relation as Dumas supposed. Out of 67 elements whose atomic weights are fairly well known, 38 are whole numbers or different from a whole number by no more than one tenth. It will be noticed that quite recently the doctrine of the protyle is rendered probable in another form. The so-called electrons, which are supposed to be vastly smaller than atoms, are found, by the best evidence yet available, to have the same mass, whether derived from the atom of one substance or that of another with a different weight. Moreover, there seems to be reason to suppose that atoms or molecules may become so complex that the internal strains cause them to be unstable, as in the case of radium, and that these protyles are given off incessantly without appreciably reducing the mass. If this spontaneous decomposition be assumed and the materials given off are manifoldly smaller than hydrogen atoms, then no experimental verification of the proportional relations of the protyle to the atom

could be expected in the usual channels, and the objections to the hypothesis in the new form disappear.

Another set of corespondences has given rise to what is known as the periodic law. J. B. Richter, as early as 1798, made some suggestions in this line, and soon after the atomic hypothesis was formulated, Doebereimer called attention to a certain regularity in the series of combining weights. Pettenkofer tried to arrange the atomic weights of similar elements in arithmetical series, Lenson hoped to group all weights in triads, and, later, Newlands announced the law of octaves and enjoyed the ridicule that usually attends the premature recognition of a new fact. Finally, Lothar Meyer and Mendeljeff contemporaneously (1869) announced that properties of elements are periodic functions of their atomic weights. In this way, curious analogies in mathematical proportions were brought into relation with similarities in the properties of elements. A very remarkable regularity occurs with respect to the valency of the elements. An indication that the discovered correspondencies have some counterpart in nature is found in the fact that Mendeljeff was able to predict in advance the characters of elements to fill the vacant places in the series; and these predictions were verified to a considerable extent on the discovery of the corresponding substances.

Difficulties in applying the law of Gay-Lussac to compound gases like HCl led eventually to the recognition of the theory that atoms in a gas join to form groups called molecules. Gay-Lussac's law, therefore, runs: "The specific gravities of gases stand to each other in the ratio of their molecular weights."

The molecules in a gas are supposed to be moving in all directions with very different velocities and are continually encountering each other. The molecules will encounter each other less frequently the farther apart they are, and all the more frequently the larger their cross-section. The mean free path is directly proportional to the space alloted to each molecule. J. R. Mayer, in 1842, deduced from apparent loss of heat during expansion of a gas and the fact that this expansion in a vacuum does not occasion such loss, the idea that the heat is converted into energy. When the gas is com-

pressed, the work done is transformed into heat. This led to the doctrine of the conservation of energy.

As already briefly alluded to, considerations connected with specific heat and the kinetic theory of gases seem to show that there is intra-molecular energy, which may be conceived as expended in vector, i.e., rotational motions.

A remarkable character of molecules was laboriously evolved from apparent discrepancies in the results of chemical analyses, which seemed to point to different properties of bodies with the same composition. Franklin, in 1852, discovered that one atom of zinc, arsenic, etc., had its combining tendency satisfied by a definite number of univalent elements or radicals of whatever kind they might be. An atom of carbon, for example, can unite with four other univalent atoms or radicals.

With the law of valence a new vista opened before the molecular student. The valences were also found to form a series corresponding to the periodic law. It will be seen that, putting aside the assumption of materiality as a mysterious conveyor of properties or activities, the atomic hypothesis has been the means of revealing a large series of quantitative ratios or correspondences, the value of which to science is something wholly apart from the significance of the material atoms in which these correspondences are supposed to reside. They are all correspondences in force, or, better, in form or amount of energy.

The fact that there were exceptions to the application of the general law of valency, led to a search for variations in the form of the atom to explain the variation. Van't Hoff, in 1878, advanced such a theory. He assumed that the chemical attraction between molecules is due to gravitation, and that, if the form of the atom were other than spherical, the intensity of attraction at the surface would have a certain number of maxima dependent on the form. If the thermal motion of the atom were rapid, only the strongest maxima would be able to retain their atoms, and valency would be greater at a low than at a high temperature, and this is the case.

Van't Hoff extended his theory by formulating a tridimensional space relation for atoms. He supposes the valencies of the carbon

atom, e. g., to act at the four summits of a tetrahedron. Wislecenus has shown that this theory gives an intelligible explanation of the existence of more isomers among unsaturated compounds than indicated by the ordinary structural formulæ.

Although this theory is of the most hypothetical kind, it has been extended to form the foundation of a complicated stereochemistry, the applications of which have also a bearing on crystallography.

We know of no matter without energy, or rather, we postulate matter only from the energy perceived. Energy is defined as of such a nature that *it is not possible for any masses affected with any kind of energy to exist together.* (It will be noted here that the fact that there are "masses" affected by "energy" is assumed without any shadow of proof.)

Mass is used as though it somehow represented "amount of matter," but, in reality, it is expressed in units of a force, and reasons may be given for using energy instead of mass. It is generally agreed to represent kinetic energy by the formula $\frac{v^2}{m^2}$, when m equals mass and v equals velocity of the moving body. Potential energy will then be represented by fs, where f equals force or measure of striving to change place, and s the space passed over by the point considered in the change of state. The general law that in energy the intensity must have the same value in all parts of the system is interpreted to mean that

For kinetic energy velocity equals intensity,
" potential energy force equals intensity,
" heat energy temperature equals intensity,
" electrical energy electromotive force equals intensity;

and that, whenever the intensity varies in different parts of the system, the latter is in a state of unrest until equilibrium is restored. In all these expressions one factor is quantity and the other is intensity; in electrodynamics, for example, the conception is that the quantity of electricity is the real thing at the bottom of electrical phenomena, and the second or electromagnetic force or tension is an intensity. (Whatever value this analysis may have in providing

an expressive terminology, it must be remembered that the real thing is the electrical energy, and that the separation into two factors is as illusory as the dualism between matter and its properties.)

Clausius was led to conclude that some molecules in electrolytes are decomposed in consequence of their collision, and that these parts, being separated, are available to effect the transport of electricity generated.[3] And it was later decided that solutions of salts and strong acids and bases contain these substances largely disassociated as ions. This theory of electrolytic disassociation has proven quite fruitful.

Up to the time of Boyle, the conception of a chemical element was not that of a substance, but of a property or a plexus of properties, so that the presence of an element in a substance was recognised through the possession by that substance of a certain property, and it may well be that little has been gained philosophically by the new idea that elements are undecomposed residues of natural substances.

From the chemical side, the atomic hypothesis seemed well justified. It became a vast and complicated structure, coherent and serving to join in an intelligible system the wonderfully varied mass of facts accumulated by thousands of workers in this field. The brief summary given will serve to indicate the diversity of the problems and the methods of solution. Like gravitation the theory was "proven" and adopted in all the practical work of chemistry and was taught in all schools as an established dogma, and yet, like the theory of gravitation, it is undoubtedly false in its present form. It is a common charge against science that it is lacking in stability and that the accepted theory of yesterday is discredited today. The criticism indicates an entire misconception of scientific

[3] By Clausius's formula, the free path of molecules has been calculated as, for example, that of oxygen at .00 000 38 in., of nitrogen at .00 000 36 in., of hydrogen at .00 000 67 in. From data so secured, the average number of collisions per second experienced by molecules of various gases at 0 deg. C. and atmospheric pressure, as follows:

Oxygen, 4 410 000 000 per second,
Nitrogen, 5 021 000 000 per second,
Hydrogen, 10 040 000 000 per second.

method. Every theory which serves to bring disconnected facts into harmonious relation has truth in it, and a rejection of a theory in its definite form, after it has served its purpose, is not to discredit its utility. The relations exist and each new theory serves to exhibit these relations more completely, till the approximation to complete harmony, i. e., explanation, is reached.

It became evident when the attempt was made to apply the atomic theory to physical problems that it was insufficient or incorrect. The emission theory of light proposed by Newton, on the basis of the rectilinear factors in its propagation, proved incapable of explaining the transverse vibrations indicated by the phenomena of polarisation, etc. This and many other insufficiencies led to the necessity of recognising an imponderable ether, which, nevertheless, was obliged to possess many of the characteristics of the homogeneous solid; and thus it came about that two contradictory concepts contrived to occupy the field together, and matter was supposed to occupy the same space with continuous ether and to be acted upon by it, while having none of its properties. A third entity, energy, by which alone ether and matter can be known, was postulated as acting upon and through both. Curiously enough, the very power of acting which is all of energy is impossible without ether and matter; and we have the third absurdity of an agent which cannot act alone, endowed with the power to act, when it comes in contact with matter, in which it immediately develops properties which have no active existence, except as acted upon by energy.

These philosophical absurdities are tolerated by those physicists who clearly recognise them, because of the difficulty of providing a practicable substitute for the elaborate systems, which have grown up in the two allied domains of physics and chemistry within the last few years.

Now, having spent a hundred years in founding and perfecting the atomic hypothesis and bolstering it up with etheric creations of imagination, nothing is more characteristic of scientific spirit than that science should make every effort to destroy or replace it. This is the work of the twentieth century.

Newton was satisfied with the solid singleness of the Lucretian

indivisibles, though he too found the ether a necessary adjunct. The defects in the atomic hypothesis are nowhere more evident than in the characters of the so-called ether invented (one can hardly say discovered) by Faraday and Clerk Maxwell. But even after inventing such a medium, it was not found possible to invent properties for it that would satisfy the conditions. A gas will not execute luminous vibrations and the anomalous solid it was once supposed to resemble could have no stable equilibrium. Material status is denied it, yet without it we are told, there could not be gravitation, and yet weight is fundamental to atoms. Without the ether atoms could not communicate. Matter is not conceivable apart from the medium which transmits its activities. Observe here that the very qualities or attributes, by which alone matter is supposed to be known, are "inconceivable apart from this invented ether which has none of them." This sounds suspiciously like nonsense.

This medium is essentially limitless and universal. It is a short step to the denial of this matter which thus plays hide-and-seek with our reason. This Kelvin did by using Helmholtz's vortex ring phenomena to illustrate a kind of atom composed of ether by the isolation of portions of the ether affected by vector motions. Such vortex atoms were found by mathematical calculation to be capable of permanent separate existence, by virtue of the peculiar form of their activities. Their indispensable matrix is a perfect fluid.

By going a little further, Professor Larmor has urged that atoms are foci of etherial strain. But, putting aside the seductions of this line of thought, whose mathematical abstruseness has hindered its popular acceptance, let us pursue the downward career of the atom.

Lockyer urged consistently from the results of his spectroscopic work, that in the furnaces of the sun, matter exists in a still more elementary condition than the atomic. Through what is called the "Zeeman" effect, magnetic phenomena are made to give confirmatory evidence of this suggestion. But it was a result of the investigations of greatly attenuated matter in Crooke's tubes that the evidence became most convincing. When electrodes are introduced into such a glass tube and the air exhausted, till the pressure is, say, one one-

millionth of an atmosphere, an electric current, in its passage, develops peculiar phenomena. It is now borne across the partial vacuum by a stream of particles from the negative pole, and these particles are invisible until they impinge on the glass, when they become visibly luminous or phosphorescent. It is found that the stream is susceptible to magnetic influence, and, for this reason, it is supposed to be molecular. The discharge tends to describe a circle about the line of magnetic force as an axis.

This "matter" was described by Crookes as being in a fourth state, as it does not perfectly obey the laws of solids, liquids, or gases; it is, in fact the so-called "radiant matter." These "cathode rays" pass freely through thin metallic films and discharge electrified bodies by making the surrounding dielectric temporarily conductive. These rays also affect photographic plates.

Oxygen, at one-sixteenth pressure, is exactly as permeable to cathode rays as is hydrogen at normal pressure; and this fact is very significant.

"Roentgen rays" are also produced by bombardment of walls of vacuum tubes by radiant matter, but are enormously penetrative of many opaque substances. They cannot, however, be diverted from their paths by magnetic influence. For this reason, cathode rays are said to be corpuscular, and Roentgen rays are etherial, movement alone being supposed to be transmitted. Here, however, is a case where the properties of the two things are exceedingly similar and the fundamental distinction between the behavior of material particles and etherial vibrations breaks down. We may be forgiven for doubting the existence of such fundamental distinction, at least in this case.

But, returning to the cathode ray material, it is concluded that it is composed of neither molecules nor atoms. Whatever the kind of gas in which they are produced, their properties are identical. Perhaps we have here the "protyle" or primeval material—the *Urstoff* of earlier speculative physicists.

These infra-atomic elements can only be produced by means of electricity and are always "charged," and this lends plausibility to the description by J. J. Thomson of cathode rays as "convection

currents" of electricity. He adduces reasons for believing that these "corpuscles" are one-thousand times lighter than hydrogen atoms, and that they form "invariable constituents of the atoms or molecules of all gases and presumably of all liquids and solids." If these are ultimate electrical units, the name "electrons" is appropriate for them. A confusion often arises here by employing "ion" for "electron," and physicists speak of "ionising" the air. Gases are 'ionised," when their molecules are broken up into smaller particles or ions, each associated with an electron. The electrons have the power of electrical conduction. Ideas here are as yet very hazy, and the minute discussion of them here would be unprofitable. Perhaps, the tendency represented by Larmor to believe that an atom is an aggregate of electrons in vector motion, that its mass is proportional to the number of these constituents, and that the interatomic forces are electrical, is now in the ascendent.

These suggestions might have been relegated to the limbo of defunct theories, but for the startling and rather disconcerting discoveries, in connection with radiant matter, recently made in uranium compounds and related substances. Uranium, thorium, and radium have the highest of known atomic weights, and this fact suggests that if atomic equilibrium really be unstable, the effects of interference or incipient break-down should be observed in the case of these elements, if anywhere. In fact, the rarity of these metals may be due to the fact that they are unstable and liable to subversion or inorganic decomposition. Radiation, like phosphorescence in animate matter, may be a species of decay.

Electrical tests of radio-activity carried on by Rutherford and Soddy at Montreal promise a quantitative measure of this activity. The ionisation of a given quantity of air was measured by the effect on a constant current, as read by an electrometer. Thus, the leakage of electricity under the influence of the radiations can be measured very accurately and a standard of comparison secured.

Thorium and radium give off continuously three kinds of rays called *alpha* (atomic), *beta* (cathodic), and *gamma* (etherial). The first or alpha rays are believed to be composed of atoms (perhaps of helium) and are charged with positive electricity, and they can be

deflected by a magnet. They move with a velocity of some 16,000 miles per second and are powerful ionising agents. Beta rays, on the other hand, are cathodic, and the particles may be one one-thousandth of the weight of hydrogen atoms. They are positively electric and highly actinic. They are dispersed unequally, forming what has been called a "magnetic spectrum." Gamma rays are believed by Madame Curie to be ultra-luminous vibrations. They are not deflected by a magnet.

Besides the above, the substances above named slowly give off what appear to be gaseous emanations that can be condensed by intense cold. By means of these emanations are explained "induced" radio-activities in objects adjacent to radiantly active materials. These emanations are self-luminous. From experiments so far made, Professor Rutherford inclined to the belief that the alpha rays are really helium atoms and the emanations also behave like this element. It is possible, then, that radium spontaneously decomposes in forming helium at ordinary temperatures.

The production of heat by radium, independent of other source, is a significant fact and has been supposed to show that this element is continually liberating atomic energy.

Hitherto, we have had to do with molecular effects; here it is possibly a case where deeper reservoirs of force residing in the atom have been tapped. If a radium atom contains 258,000 electrons, J. J. Thomson concludes that the diminution of the intrinsic energy of radium atoms by one per cent. would keep up the emission phenomena for a period of 30,000 years. If 3.6 grammes of radium existed in each cubic metre of the sun's volume at the surface, it would be sufficient, according to Wilson, to supply the totality of solar radiation. These guesses serve merely to suggest what a mass of energy may lie concealed, entirely inappreciable to scientific instruments, in the "atomic" structure of the most tenuous gases. A gramme of radium, according to one author, has power enough to raise 500 tons a mile high.

But this fatal quality of dissociation appears to be universal, as Sir William Crookes says. Bewildering as is the mass of new facts and still larger crop of new speculation, it is clear that atoms in the

old sense can no longer be accepted. With the atom, a whole world of varied and enormous activities has been discovered, and the door out has been left ajar so that these forces can no longer be kept sealed. Pandora's box is open and the plague of new speculation is abroad.

The simplest view that can be taken is that the integrity of what we call an atom is in the nature of an equilibrium. Mathematical and physical experience shows that vector motions (rotational energy, etc.) are different from energy in rectilinear or radial translation, and that there may be a high degree of independence between these two sorts of energy, and that two instances of vector motions may mutually influence each other in various phases, depending on their correspondence in time and mode. The solenoid illustrates this point roughly.

Physics is inclined to suggest an electrical force as behind all so-called material phenomena, and the recent results of radium investigation tend to support the suggestion.

Meanwhile, one result is plain: cosmological speculation can profitably go no further than to take the actual data of experience, which gives us only energy in various manifestations, and it is by no means clear that anything will ever be gained by seeking an explanation of the ultimate fact of experience by invented "carriers," "media," postulated to "explain" what is by nature inexplicable. Further discussion may, however, be postponed till we have considered the other material alternative.

"We are acquainted with matter only as that which may have energy communicated to it from other matter. Energy, on the other hand, we know only as that which in all natural phenomena is continually passing from one portion of matter to another."—*Maxwell.*

THE PLENUM.

The defectiveness of any atomic conception of matter appealed to a certain class of minds, from the first. As a mere abstraction, it seemed unthinkable that the continuous translation of force through space could take place if space were but partly filled. Atoms, if capable of independent action at all, required to be separated from

one another by such spaces. Nature, especially as we have said, the nature of the human mind, abhors a vacuum, and it was inevitable that the atomic hypothesis should be substituted for or supplemented by, the concept of a plenum or something filling space completely.

Even Anaximander seems to have had some such idea in his ἀρχὴ or *Urstoff*. This unlimited, undefined, but not immaterial, ground of energy was in so far dynamic, as it possessed the eternal property of motion, but it was not freed from the materialistic tendency of the Ionic school in which it developed. There was a combination of the energic with the plenistic ideas, which were too vaguely expressed to have more than an historic interest.

The plenum of Descartes was something like extension. There are two substances, spirit and matter. The attribute and essence of matter is extension. This dualism was bridged by Malebranche, but there is nothing to explain the nature of the universal plenum. Descartes does explain light as generated by a pressure throughout an infinitely elastic medium filling space. Newton, though advocating a corpuscular theory of light, also taught that heat may be conveyed through a vacuum "by vibrations of a much subtler medium than air," and adds, "is not this medium the same with the medium by which light is refracted and reflected?" He also employs the ether to account for gravitation. Hearing and animal motion he also supposed to be brought about by the vibrations of ether.

The theory of the ether, as now universally taught, results from the necessity felt for a medium to transmit energy from point to point. Light, for example, moves at a finite rate from the source of generation, and, in as much as the phenomena of destructive interference seem to forbid the idea that light is a substance emitted from the luminous body, as held by Newton, the only recourse was to postulate a medium of some kind in which disturbances may be propagated in all directions. We have the analogy of sound. Sound waves are not propagated *in vacuo*. It requires a medium, in this case air or some fluid or solid substance. In like manner, it is supposed, there must be a medium for the light, heat, and electrical vibrations.

Huygens is credited with being the real inventor of the etherial hypothesis in its present form, and it cannot be denied that the doctrine has been most fruitful. The present tendency is perhaps to consider even the phenomena of matter itself as manifestations of energy stored in ether. Potential energy is considered to be energy stored in the ether and may be simply motion of the ether, so that all energy will be found to be, as it theoretically must be, kinetic.

Two properties must be assumed to satisfy the conditions, for which ether was invented, viz., elasticity and density. In the case of a vibrating elastic solid, the energy is half in the form of kinetic energy due to the vibratory motions of the parts of the body, the other half being potential or stored up in the distortion of its parts. It has been found that the vibrations of light are of such a nature as would be impossible to either liquid or gas, so that something analogous to the solid state is required. This state is found by mathematical research to be unstable. It results that the ether has no scientific footing, but has the anomalous status of being something of pure invention, failing to satisfy the conditions which alone led to its invention.

As a matter of fact, all the discussions of wave phenomena would be just as intelligible as they now are, if the idea of ether were eliminated. Or, rather, this would be the case if the mind would disabuse itself of the analogy of water and sound vibrations, which seem to require a medium. Here the more suitable expression is that waves of sound are alternating forms of activity recognised in conditions satisfied when vested in what we call liquid or other matter. It must not be forgotten that the energy involved in sound is not lost, when the sound wave is prevented from proceeding by an interposed vacuum. Its critical point is reached, and it assumes another form. These modes are really expressions of interference of forces, residing, as we are wont to say, in the forms of matter called media for sound waves.

Optics talks of the kinetic energy of a vibrating particle, distribution of energy in the case of a medium disturbed, etc. All of these concepts lose nothing if divorced from the idea of a medium.

A study of electro-magnetic phenomena has been used to fortify the ether hypothesis, and, by a curious fatality, it now seems that its perfection will but serve to complete the overthrow of that theory. The ether about an electrified body is supposed to be affected or thrown into activity. When thus active it is polarised. When the body is discharged the activity ceases or is dissipated. Alternating electrical charges are accompanied by changes of state or vibrations of the ether, and, if the charge be varied periodically and with sufficient frequency, we have a vibration at each point analogous to, and perhaps identical with, what occurs in the propagation of light. Light and heat waves have been reduced to the same category, both being waves of electrical polarisation. Professor Hertz's experiments related to oscillating discharges having a period of about one 30,000,000th of a second, and reflection and interference of electro-magnetic waves are ingeniously brought within the sphere of observation. Reflected waves interfere with direct waves as in the case of sound. Most of the experiments usually carried out with light and heat waves were successfully tried with the electro-magnetic vibrations. From the mode of production, it follows that these vibrations consist of transverse vibrations, and that they are plane-polarised. Without carrying out the comparisons between the electro-magnetic and light vibrations further, we may add that, according to the electro-magnetic theory of light, the vibration is a transverse periodic disturbance attended by electric force in one direction and magnetic force in the perpendicular direction. Comparison of velocities and refractive indices reveal the required harmonies. The original conjecture of Faraday (*Experimental Researches,* 3075) that the electro-magnetic action may be a function of the ether, seems about to be confirmed, except that by the ether we are brought no nearer to a solution of the general problem.

Even if the difficulty involved in the supposition that an elastic or compressible medium must be discontinuous be ignored, and we assume that a medium may be homogeneous and continuous as regards density, and yet may be really heterogeneous by virtue of its motions, as in the case of the vortex atom, in a perfect liquid-solid, still are we no better off with our medium than we would be, if we

substitute energy, instead of mass, in our equations and do away with the material element and medium altogether.[4]

There is an important fact which physical theorists are prone to forget, and, by neglecting it, are led to state hypotheses as proven facts, viz., we cannot know atoms or molecules individually, but, if at all, *only in the aggregate,* and what we infer of their structure must be by observing, experimentally, the gross results of their interaction in masses. For example, according to Avogadro's law, there are simple volumetric relations among gases when they combine. The densities of gases are proportional to their molecular weights. But the statement of Avogadro's law, in the usual way, that "all gases (conditions being the same) contain the same number of molecules per unit of volume," is pure hypothesis, yet it passes in physical literature as "established fact." The question of the nature, nay of the existence of molecules, is begged throughout.

Any theory, molecular or otherwise, which can acceptably *explain* the constitution of the physical universe, must bring into harmony the different facts which pass under the names *inertia, elasticity, attraction,* and *stability.* But, by explaining, we do not mean the clearing up of the ultimate *why* or the final *what,* but the arranging of all the facts in a congruous system which is the ultimate

[4] An illustration of the tedency of modern physics in relation to the concept of materiality, is given by Drude's *Lehrbuch der Optik,* which is devoted largely to the mathematical development of the electro-magnetic theory of light. In this work we find such expressions as "The vacuum (the free ether)," "the velocity of light in empty space (the free ether)," and the following more definite statement: "The concept of the absolutely quiescent ether is most simply and naturally expressed if we understand by ether, not a substance, but simply space provided with certain physical peculiarities." The naïve innocence of metaphysical taint in this statement, where space is supposed to be clothed with certain physical attributes, may seem amusing, but we see at least a recognition of the difficulties inherent in the postulate of material media. The magnificent hypothetical structure erected by H. A. Lorenz (*Versuch einer Theorie der electrischen und optischen Erscheinungen in bewegten Körpern,* Leiden, 1895) rests on the assumption that the ether is always in complete state of rest. The chief value of the electro-magnetic theory is that no special assumptions are necessary for the propagation of light, but its laws follow directly from those of electric and magnetic forces as already worked out, or, as Drude says, "It does, indeed, represent a remarkable advance in natural science when two hitherto unrelated realms, like optics and electrical science, are brought into relations by mensurable control."

how. The dynamic view is that the complete comprehension of the *how* is all that we can ever know of either *what* or *why*. It is not sought to "unify the conception of chemistry and physics and consolidate these sciences into one grand science of matter," as suggested by Risteen, but, on the contrary, it finds the essence of things in their behavior and is satisfied, if it may continually approximate to a knowledge of the forms of these activities, which to know is to *understand* the physical universe. Nor does one doubt that the energy which finds expression in material terms is, in last analysis, of one kind with that whose complex trajectory is interpreted in consciousness.

When the physical demonstrator by means of a box punctured on one side and furnished on the other with a taut membrane, by tapping on the membrane, projects smoke rings across the room and shows us how the smoke curls in vortex-flow along the axis of translation and how two such rings may be made to interfere and intertwine in most complicated fashion, he is careful to tell us that the smoke which we see performing these amusing antics has nothing to do with the phenomena, except to make them visible to us. The vortices would be there just the same, if no smoke were in the box. So when the vortex atom, which comes the nearest at present to affording a scientific concept of the physical unit, is introduced, Lord Kelvin is careful to exclude from the ether, in which such atoms are supposed to exist, all material postulates. It must have the character of a *perfect fluid*. Thus, we see the postulate of materiality is but the smoke for making the vortices comprehensible to the lay mind. A brief analysis of the vortex-atom, or, better, the vortex unit, will make this clear.

1. Helmholtz, in his definition of vortex units by mathematical process, showed that the fluid in which such vortices exist must be frictionless, homogeneous, and incompressible. Such a combination is incompatible with what we are supposed to know of matter, but granting these conditions, a vortex could never be produced or destroyed in such a medium, and it follows that it would be conserved forever, or that it would exist as long as the medium continues.

2. Such a vortex would always contain the same portion of the fluid. It moves as a whole—it is not alone the motion that is propagated, as in wave motion. Thus the energy is doubly identified with the fluid (or conversely) both as to permanence and as to content.

3. Now, compare these points with the definition of matter by Lord Kelvin, the other great student of vortices. "Matter is the rotating parts of an inert perfect fluid which fills all space, but which, when not rotating, is absolutely unperceived by our senses."

If the statements under 1 and 2 are correct, the expression, "when not rotating," is inapplicable; for, if not rotating, this fluid can never be made to rotate, and, if only part be rotating and the rest not, then the part not rotating cannot affect that which is, nor can it be affected by it—it is "inert." If it existed we could never know it, nor could we comprehend in what its existence consists. It would be a case of "pure being," equivalent to "non-being" in the popular nonsense, improperly attributed to Hegel.

We see that the only things which could cause the vortices to affect one another *are their respective activities.* If matter is elastic, it is because there are such things as repellant phases of activity; if there be attraction, it is because certain phases coincide or have congruous periodicities; stability and individuality are inherent in the nature of vortex or vector activities, corresponding to intrinsic or genetic modes; and, finally, inertia is but another name for spontaneity, the last irresolvable, constituent attribute of energy.

It must be noted, in passing, that vortex units are not necessarily vortex *rings.* A better analogy is, perhaps, that of a spheroid of "free path" or field of activity in which the spheroid is tending constantly and in all parts to be everted. A ball continually turning itself wrong side out by a kind of convection motion is a convenient representation. This is a fourth-dimension motion of great mathematical complexity.

Doubtless, every genuine discovery made by the newer molecular physics, however erroneously applied, will find a place in the new dynamic science.

ENERGISM.

What has already been said, while giving but the barest outline of an exceedingly complicated subject, may serve to illustrate the difficulties in the way of any materialistic hypothesis as a foundation of practical science, not to mention the philosophical difficulties encountered at the outset.

There remains but one possibility—the appeal to energy. This method of approach seems very difficult, especially to those who have served an apprenticeship to modern physical science, because the idea of a medium or vehicle of force has become so strongly intrenched in the didactic literature and in the formulæ with which much of the practical work is done. It must be remembered, however, that the fact that a velocipede is equipped with three wheels does not prove that a bicycle may not move faster. If matter is unnecessary as a practical utility, the sooner this conception can be removed the better for the progress of science.

Historically, germs of the energic idea have always existed. It may seem fanciful to discover the nucleus of the dynamic concept in the dawn of philosophy, but in the ἀρχή or *Urstoff of* Anaximander we have a ground of energy, which, while not purely dynamic, and developing in dualistic form in antinomies of heat and cold, still indicated a naïve appreciation of energy as real, apart from a material substrate. This method of thought was common till Dalton, with his atomic hypothesis, gave it a long sleep. Malebranche postulated an absolute substance which includes all things and also the *idea* of all things, to resolve the dualism of Cartesian substance. Spinoza, too, denies the possibility of numerous substances, and demands an absolute substance, which is the real ground of all existence and the source of all reality. All expression of this reality is a limitation or negation (*omnis determinatio est negatio*). Matter and spirit are the two forms of self-limitation in which absolute substance appears. These are the attributes in the form of which substance reveals itself. There may, indeed, be many attributes in the substance, but, by the nature of the human mind, we distinguish subjective and objective.

In Spinoza we find the Cartesian dualism between matter and spirit maintained. There is a parallelism, but mind cannot work on matter, nor can matter influence spirit. These two are phases of one reality, so that there is correspondence but no interaction. (It should be observed that this is a much deeper view than that expressed in the current psycho-physical parallelism of psychology, which, as usually formulated, means nothing but the statement of an observed coincidence.)

The reconciliation of these difficulties is to be found in energism, which explains that neither body (matter) nor spirit (soul) exist as independent entities, but both are ways of experiencing the same energy. As Spinoza admits, the distinction between matter and spirit is of our own creation. When I feel a sensation and discriminate my feeling of it from some outside activity, this is a valid discrimination for *me*. The whole chain of activities between the outside source of light and the accommodation activities in my organ, form parts of a segment of activity, which *in itself* requires no explanation beyond the fact of spontaneous *doing*. The things I think about this (objective aspect) and the thinking about it (subjective part) cannot be distinguished as existences (matter and spirit) parallel to each other. Whatever truth they have inheres in the activity producing both.

At the present time, science represents the remarkable and anomalous spectacle of a vast mass of chemical and physical literature permeated and dominated by materialistic-mechanical theories. The entire pedagogic machinery, including text-books and teachers, is adapted to impart a strict construction of matter and energy as the twin realities in the physical universe, while, at the same time, the foremost investigators, and the authors of some of the very texts referred to, have openly or by implication abandoned these postulates.

The student of Ostwald's *General Chemistry,* for example, will find little to prepare him for such views as those presented in his address at Luebeck entitled "The Overcoming of Scientific Materealism."

As this writer observes, there are collected in the idea of matter

numerous elements of sensuous experience, like weight, extension, chemical properties, etc., which are found by experience associated with mass and connected proporionally with it, so that "the physical law of conservation of mass was transformed into the metaphysical axiom of the conservation of matter." "It is important to note that in this extension a number of hypothetical elements have been wrought into what was originally an entirely non-hypothetical notion." The necessary results of this hypothetical matter-hypothesis lead to absurdities, to which we have become so accustomed as hardly to notice them. As Ostwald says, speaking of the assumed persistence of the original substances in compounds: "When we consider, however, that all that we know of any substance is a knowledge of its properties, we see that the assumption that a definite substance remains, although it no longer retains any of its properties, is little removed from nonsense."

Nor is this all, for, having adopted the matter postulate, it is necessary to supplement it by the doctrine of energy. As matter is quiescent and unalterable, it is necessary to connect it with something to correspond with the changes known in experience. This constant cause of motion is energy, and this, like matter, is supposed to be a constant in the sense that its total amount is never increased or destroyed. Ostwald, again, says, respecting the mechanical construction of nature built upon the two above formulæ: "One usually does not observe to what extraordinarily great extent these generally received views are hypothetical not to say metaphysical. On the contrary, it is customary to assume that they express the maximum of exact formulation of actual relations. On the other hand, it must be emphasised that a proof of the consequences following from these theories, that all the non-mechanical processes like heat, light, electricity, and magnetism, are actually mechanical, has not been afforded in a single case."

We have traced in outline the transformations of the optical theory. The others are in no better case.

But if we are deprived of the assistance afforded to imagination by the concept of moving atoms, how are we to conceive of the world of matter and energy at all? Ostwald answers this question very

uncompromisingly: "Thou shalt not make unto thee *any* graven image or likeness. It is not our duty to view the world in a more or less dull or irregular mirror, but rather, so far as the structure of our minds will permit, to view it directly." The function of science is to bring into such definite relations *realities,* i. e., demonstrable and mensurable quantities, that when one is given the other may inevitably be assumed.

This is the energic point of view—not the substitution of one complicated hypothesis for another, but the eliminating of the hypothetical, so far as possible, and the appeal to facts of experience. To the criticism that the concept is empty and lacking in clearness as compared to the material view, we must reply that sensuous perception is a reaction induced by variations in the intensity and form of energy and nothing is gained by postulating media or bearers. Remember that matter is the abstract and energy is the real. The external reality is a reality of relation which the mind makes into *substance,* but substance is not necessarily *matter.* A classical English passage speaks of *faith* as substance.

When asked what advantages are to be expected from a resort to energic methods of notation in dealing with natural phenomena, the energist answers: "First of all, the very important one that by this means we have a natural science of fact and not of hypothesis. We no longer inquire about forces that we cannot demonstrate operating between atoms which we cannot observe, but, in forming judgment of a process, we examine the kind and amount of energy entering and leaving." This method is that proposed by Kirchhoff who wished to supplant explanation of nature by description of nature.

Physics shows that the ratios used in her computations are without exception ratios of different kinds of energy. Aside from the two forms or categories of perception, space and time, energy is the only measure. But space and time are measured by energy alone, for energy forms their only content. The predicate of matter cannot find a mathematical expression in eqations of energy. Only commensurables can be compared.

When physics repudiated force (in the usual sense) and chem-

istry reputiated matter and both cry "back to nature—back to experience," what science is to reap the benefit, or rather is to fill the breach? There can be but one answer. Psychological moments alone remain reliable and trustworthy measures of quantity. In last resort we discover (what has always been known but never realised) that the only energy we really know is that which we ourselves generate. The axiom at the bottom of all science is that the force impinging on my sensorium is commensurate, according to some law, known or unknown, with the reaction within my kinesodic system. In other words, the only real measure is mental reaction thereto—sense of effort or strain. Everything quantitative in science has to be interpreted in terms of effort before it can be recognised in any consciousness. It is customary, e. g., to reduce all measures of physical quantities to scales on some dial, let it be of an electrometer, ammeter, barometer, thermometer, photometer, or the like. The reading of such scales, is in final analysis, reducible to muscle-strain estimates in the eye-muscles, and the graduation of the scales may be reduced to a function of muscle-strain estimates in the hand, etc. It would seem, then, that we really estimate in homo-ergs or man-powers. May it not be possible to reduce all to a standard, say of "psychs"? The suggestion is not so far-fetched as it may seem, but the objection we at first meet is that there is no assurance that a unit of reference that would be true for me would be absolute for all men. A John Smith-erg might not equal a Joe Brown-erg. Expressed scientifically, the neural mechanism of man is so complex and the number of variables is so enormous and its processes so varied that it is difficult to discover a constant for a standard of reference. The resistance offered by the organism to external influences varies. Attention is not a constant, and all mental phenomena are functions of attention. In this dilemma the mind has recourse to an indirection. Being unable to find any single constant, it utilises a ratio. Under the assumption that the variables in perception affect both terms alike, then the result will be the same whenever the ratio affects the mind, no matter what phase attention may be in. This is a process of comparison.

To illustrate crudely, I may not be able to tell how far I travel

by summing up the total effort expended in walking, but I am able to reach an estimate by comparing a constant of effort in walking multiplied by the time employed, with a similar effort multiplied by twice that time. The mind very accurately detects differences when it fails to measure their amount. $(D : te :: D' : 2te) = (D = 2D')$, where e is a constant of effort put forth at any time, i. e., the habitual gait in our illustration. Very little experience shows that both factors, time and effort, vary below the threshold of consciousness and do not vary uniformly. If they varied proportionally and the equation could be written $D : te/x :: D' : 2te/x$, it would still be available but it must be written $D : te/x :: D' : 2te/y$, and cannot be solved. It having proven useless to attempt to construct a constant ratio on the subjective basis only, i. e., entirely on the basis of internal experience, values for x and y, i. e., for the variables in our equation, must be derived from without. The uniformities in experience, such as the succession of day and night and the annual astronomical recurrences, are used and continually corrected, till they can be represented by a contrivance like a clock or metronome. In this way, the internal time estimate becomes definitely linked to external changes. In similar ways, the other term, say, the effort in walking, is linked to external correspondences so that x and y become known in terms of t and e and the ratios t/x and e/y can be used in our construction of the world of experience. At the same time, it must not be forgotten that the ultimate standard is internal unit or constant of effort, without which the entire external mechanism would be valueless.

We have seen that the three categories of experience are time, space, and mode. In these three forms all experience is cast. Time is a necessary form of experience because of psychical limitation; two events cannot co-exist in consciousness. This is a result of the unity or individuality of experience. The psychological equivalent is sequence.

Space is likewise a result of the limitation of experience. Effort implies change. The external equivalent is motion. These two, sequence and motion, are the generators of the extended continuum of experience, which is filled in by the form of experience called

mode. Two modes may be distinguished, identity and difference, or, rather, mode consists in the distinction of difference from identity.

While the mind is incompetent to make quantitative distinctions directly, it has the most remarkable clearness and certainty in dealing with difference. Psychologists have used all their ingenuity to utilise this ability to discriminate differences as a basis for a quantitative psychological science. It would appear that a series could be made after the analogy of differential calculus, in which the several terms should increase by a difference less than any assignable quantity (the discrimination quantity), and that such a series could be compared with a corresponding series of external quantities, thus giving rise to a mathematical relation that should form a quantitative unit for sense perception. Almost the only result, so far, of this effort is expressed in the so-called Weber's law that while the series of excitations increases in arithmetical ratio the corresponding series of excitations must increase by geometrical ratio. And yet even this is found to express only approximately and within narrow and arbitrary limits a relation for which no adequate or constant explanation can be given.

A fundamental criticism of attempts to use the sense of effort as a unit of measure is that two or more things are frequently confused under this head. In the first place, the muscle sense or sense of muscular effort, if we are justified in speaking of such a sense, is a sensation-complex . It is not analoguous with the sense of having originated a voluntary act. Attention, which is involved in all receptive mental acts, involves, among other things, accommodative effects in organs of sense, it may also involve accomodation phenomena in the brain itself.

The inquiry remains: Is there such a thing as effort in consciousness apart from these accommodations? A prevailing psychological interpretation is to the effect that the afferent nerve current passes over into the efferent, according to conditions of structural organisation, and that the issuing into the efferent expression produces, or is accompanied by, a sense of action, or impulse, or initiative, or effort, out of which the sense of having-done-it arises. It is even

customary to speak of the will as arising subsequent to the voluntary act as a consequence of the act. However this may be, if muscular sense is really a sensation, like other sensations, and not a direct feeling of psychical activity or participation, then our supposed quantitative unit reduces to a series of modes. Instead of a simple more or less, we have different impressions which we *interpret* as more or less. The sensation produced by a weight of two pounds is a different sensation from that produced by one pound, not a more of an identical sensation. Evidently, we are on the wrong track somewhere. This raises the general question whether it is possible to use pure modality as a measure of quantity. A light twice as bright as another does not produce a sensation twice as intense nor one in logarithmic series as compared to the series of stimuli. We do recognise identity and change.

Theoretically, it is wrong to seek quantitative measures in the categories of external apprehension, since we are seeking an internal measure. Sensations cannot give this as they are all projected out ward or externalised. Succession is, strictly speaking, all that the internal sense or inner experience can contribute.

Can it be, then, that the formal subjective measure is to be expressed in most general terms by at, where a is any attribute and t is succession or time? Such would seem to be the necessary *a priori* assumption. A test of such an assumption may be found in its applications.

Space, when filled, consists of one, and another, and another, etc. An absolutely uniform field of vision (or of any other experience, if possible,) could not be made to seem extended. This creeping from particular to particular is essentially, on its inward side, temporal, as it becomes on its outward side spatial. All our measures are now reduced to serial terms. When we say that one light is twice as bright as another, or that one star differs from another in glory, we express the results of a complicated system of judgments. If it takes me twice as long to traverse the plowed ground as the meadow with the same constant of effort, I have a measure for effort. Even here the difficulty is at once perceived

that we have no subjective time measure. We may use heart-beats, but even heart-beats are objective to the mind.

Succession and change, in last analysis, must be our subjective contribution to quantitative science, and it is useless to seek more. These forms are filled by experience, and we find our periodicity in external experience. The curious, if not altogether unexpected, result is that the soul itself has neither time nor extension.

After having appealed in vain to psychology for a complete quantitative unit, we are prepared to admit that *quantitative estimation is but one of the ways in which we affirm attribute. Its reality is neither wholly subjective nor wholly objective, but one of the forms of reality resulting from the union of both.*

If we eliminate matter as irrelevant, we have left energy, which reveals itself to us in terms of succession and mode. It produces varied sensations, and these are arranged in sequence. Our ability to recognise identity in mode gives rise to periodicity, and this is the measure of time. Some particular period, say a second, is chosen as such unit.

The negation of succession is co-temporaneity which is possible in connection with diversity of mode, and this is only objectively possible in terms of space. Two identical points have no spatial relations. All space relations are possible only upon the assumption or condition of co-temporaneity. The following psychological formulæ may be useful:

1. Sequence with identity produces periodicity = time.

2. Co-temporaneity (o × sequence) with diversity produces space.

3. Sequence with diversity produces change.

4. Co-temporaneity with identity produces intensity.

These abstractions require elaboration.

I. (Seq. × Iden. = T.) I experience a series of sensations, tic, tac; tic, tac; tic, tac; etc. One follows another in temporal sequence. But I detect a rhythm or identity. Where it not for the rhythm I should get no time measure. Thus I have succession and identity as necessary elements of temporal mensuration.

2. (o × Seq. × Diver. = S). On the other hand, in space re-

lations as such, sequence is impossible. Even when we conceive of a moving point generating a line, etc., it is always implied that at the same time the original point and all other points in the line co-exist in time and are considered together. The diversity of each point in space is represented by the locus formula, but the origin represents a constant point of reference, and time is excluded. It may be replied that time is simply ignored and diversity is all that is needed to produce a spatial measure. This is not true, for co-temporaneity is a real concept of form, though impossible in inner experience. Co-existence and diversity are possible only under space conditions. This distribution of mode and identity of time form the psychological data of space.

3. (Seq. $\times$ Diver. $=$ C.) Sequence and diversity are, in like manner, the psychological moments of change. If the sensation or sense datum be not co-temporaneous, or thought in one time with its predecessor, it has taken the place of that predecessor and there has been change.

4. (Cotem. $\times$ Iden. $=$ Int.) But, on the other hand, if the mode has not changed, but is thought into the same time, we get the concept of intensity or more of the same, or quantity. This predicate of intensity is not given in experience, but the same may be said of the others. Time is not a direct element in experience, though sequence is. Space is not a primary idea but is generated from co-existing diversities. Change is other than diversity. It is only when the temporal element is added to difference that the category of change is formed.

We have given, therefore, these fundamental derived psychic data of the second order not as subjective predicates, but as the first results of reaction between subjective and objective. If our psychological analysis has been correct, by means of these four moments it should be possible to construe all phenomena possible to experience. It may be left to mathematical physics to make the applications of these principles and the necessary substitutions in the formulæ in general use.

In conclusion, we may refer to the metaphysical results which transform the physical doctrine of energism into the psycho-philo-

sophical dogma of dynamic monism. In a little book published anonymously by Kegan Paul, Trench, Trübner & Co., London, in 1898, entitled *The Doctrine of Energy*, the author offers suggestions which deserve a wide reading. "The study of physics *can* be carried on practically as a study of phenomena—of heat, colors, sounds, forces, etc., all of which are kinds of phenomena—without the expression of any formulated opinion as to their relation with reality." "But science has been reluctant to recognise that it is now entitled to dispense with the postulation of matter. The theory, as announced by the leading men of science, has, therefore, been to the effect that there exist in the physical universe *two real things*, matter and energy, in place of one only, as commonly supposed for so long. We have elsewhere attempted to show that such a statement of scientific theory is erroneous and redundant; that science is not necessitated to postulate *two* such entities; but the postulation of energy supplies all her requirements." "Our view, therefore, is that the conception of materiality and of real matter can, in the way just indicated, be in all cases analysed into, and derived from the conception of energy; and that science, if consistent, cannot postulate the reality of matter as well. Potential energy adequately supplies the conception of a real substratum of which phenomena are the manifestations."

To the question: "How do I get beyond my presentiment? How pass from ideality to existence?" the answer is, "I never could have got beyond it or got any suggestion of the reality had I been related to my presentiment as a passive and percipient subject." I am in relation with the energic system not merely or primarily as an intelligent percipient of the transformations proceeding in it at a particular point, but also as a will initiative, to some extent, of such transmutations and capable of influencing and directing the physical process." "In my activity there is thus suggested to me a source of phenomena lying beyond the phenomena themselves." "My most incessant mental act is that by which, on analogy of my own active experience, I refer all phenomena to the underlying energic system."

We cannot go into the author's treatment of causation as a

derivative from the self-consciousness of initiative, which is then objectivised and recognised as one with the source of all action—energy. Enough has been said to indicate a close connection with the position taken by Schopenhauer in the *Fourfold Root*. "What we think under the conception, *matter*, is the residue which remains over after bodies have been divested of their shape and of all their specific qualities; a residue which, precisely on that account, must be identical in all bodies. Now, these shapes and qualities, which have been abstracted by us, are nothing but the peculiar, specially defined way in which these bodies act, which constitutes precisely their difference. If, therefore, we leave these shapes and qualities out of consideration, there remains nothing but mere activity in general, pure action as such, causality itself. Matter is throughout pure causality, its essence is action in general."

That these views will be slow in finding acceptance among the rank and file of chemists may be gathered from remarks in F. W. Clarke's "Wilde Lecture" before the Manchester Philosophical Society, May, 1903.

"When we say that matter, *as we know it,*[5] behaves as if made up of very small discrete particles, we do not lose ourselves in metaphysics, and we have a definite conception which can be applied to the correlation of evidence and the solution of problems. Objections count for nothing against it until something better is offered in its stead, a condition which the critics of the atomic theory have so far failed to fulfil."

This illustrates how, for each of us, his own particular brand of metaphysics seems harmless or not to be metaphysics at all, for this is exactly the contention, that the material hypothesis is metaphysical and has added nothing to the definiteness of our conceptions of physical phenomena, neither can it legitimately be utilised for the solution of problems. The abacus has long since been abolished from our schools, is it still necessary to our physicists, must our chemists still continue to count on their fingers?[6]

C. L. HERRICK.

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[5] Italics mine.

[6] The question might be asked, (in fact, it has been asked): "How is it

possible to get the resistance or limitation necessary for the objects of our experience out of pure energy?" "Is the element of tension and opposition in your very conception of energy?"

The reply to this should be based upon an examination of the nature of the energy concept more detailed than is germain to our present purpose. The difficulty is, probably, like nearly all philosophical perplexities, a result of our unhappy logical faculty for splitting things that ought not to be divided. We may undoubtedly think of the *word,* "doing," apart from the expression, "doing of something," but it is to be doubted whether we can think of *pure* energy at all. We think by "affirming attribute." It is still more energetically to be insisted that no real severance of the doing from the thing done is permissible. It is the old matter fallacy or the cause-effect fallacy in a new guise. If energy is to be set up in the place of matter as a power behind the throne, let us alone and we will return to our idols.

Viewed from a physical point of view, given no resistance to action, there is no energy. If we mean anything by energy, it must be valid in that it is acting. If the sum-total of universal energy were in like phase, it would be the same as if there were no energy so far as making a universe is concerned. Herbert Spencer has not lived in vain. Pure being is the same as non-being. We have had our Hegel. A non-acting deity would not even potentially be a God.

Practically, energy is called into and remains in existence only under condition of resistance. Resistance is varied and gives rise to *mode* in energy. In an earlier paper the writer defined creation as the self-limitation of creative power. This is not subject to further analysis. Having no experience with universal or infinite modes of being, we do not expect to understand what we must nevertheless postulate. If this view is open to the taunt that we take out no more than we put in and so are no better than prestidigitators, our reply is ready. If other people take out of their logic more than they put in, they lay themselves open to the charge of dishonesty. The taking out of more than is put in is called in logic "fallacy."